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THE ARTIFICIAL PRODUCTION OF THE PARTHENOGENETIC AND SEXUAL PHASES OF THE LIFE CYCLE OF HYDATINA SENTA

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THE causes that determine the transition from the parthenogenetic to the sexual mode of reproduction in the rotifer *Hydatina senta* have been the subject of a number of investigations, which have led to contradictory conclusions. Maupas was led to attribute the appearance of sexual forms to changes of temperature, Nussbaum to starvation. Punnett found that neither temperature changes nor starvation had any effect, but obtained what seemed to be distinct strains, each producing a fairly constant proportion of sexual forms, regardless of external conditions. One strain produced many sexual females (about 40 per cent.), another few sexual females (2 per cent.), and a third none at all. His conclusions regarding temperature and starvation were supported by Whitney, but the latter worker obtained no evidence of strains, finding that so-called strains of one type might break up into those of any other type within a single parthenogenetic series.

I believe I have evidence which may explain the difficulties hitherto encountered, evidence that goes far towards bringing the previous contradictory conclusions under a single point of view. I shall attempt to show in this brief presentation that the presence of substances in the water, other than food, exerts a strong influence on the inauguration of the sexual phase.

In this paper I shall speak of the male-producers as sexual females. The identity of the two has long been suspected from certain numerical relations, but more direct observations have been wanting. I have now, however, been able to secure winter eggs and males from the same parent. Since in all cases known, a female lays parthenogenetic eggs of only one sex, there can be little doubt that sexual eggs and male eggs are identical.

To test the influence of substances in the food cultures, lines of rotifers were reared in the water of some old cultures, from which the protozoa had been removed by filtering. Various dilutions of this water were used, one fourth, one half, three fourths and undiluted, as well as pure spring water. The same kind and quantity of food, a flagellate, *Polytoma uvella,* was added to each, and was found to live readily in all concentrations of the filtrate. The results of eight or more generations bred simultaneously under these conditions are shown in Table I.

Table I

	Spring Water.		Old Culture Filtrate.							
			One fourth.		One half.		Three fourths.		Undiluted.	
	Sex. ♀	Parth. ♀	Sex. ♀	Parth. ♀	Sex. ♀	Parth. ♀	Sex. ♀	Parth. ♀	Sex. ♀	Parth. ♀
	26	177	25	407	15	350	8	362	0	337
Per cent. Sex. ♀	12.8		5.7		4.1		2.1		0.0	

There is a gradual decrease in the proportion of sexual females from the line bred in pure spring water to that in the undiluted filtrate. The series in the dilute filtrate were discontinued at this point, but those in spring water and in concentrated filtrate were continued. In the latter line, nineteen complete generations were obtained without a single sexual female, while in spring water the sexual forms recurred at intervals, though not frequently, to the end of the experiment.

The experiment was repeated by removing to spring water a female of the seventh generation of the series bred, in the preceding experiment, in concentrated filtrate. The results of this change are shown in Table II. Six generations were reared in each line.

TABLE II

SPRING WATER.			OLD CULTURE FILTRATE.		
Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.	Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.
33	216	13.2	0	174	0.0

From the third generation of the series in spring water in Table II, a female was returned to the concentrated filtrate, and her progeny reared for three generations. A control was continued in spring water. The results are those in Table III.

TABLE III

SPRING WATER.			OLD CULTURE FILTRATE.		
Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.	Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.
7	110	5.9	0	107	0.0

The experiment was repeated four times, with sisters in each case, derived from lines more or less distantly related to those in the preceding experiments. These are recorded in Table IV.

TABLE IV

No. of Exp.	SPRING WATER.			OLD CULTURE FILTRATE.		
	Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.	Sex. ♀.	Parth. ♀.	Per cent. Sex. ♀.
1	44	163	21.2	0	141	0.0
2	49	64	43.3	0	128	0.0
3	7	106	6.1	0	103	0.0
4	5	76	6.1	0	85	0.0

In every case, the evidence points to the same conclusion, namely, that the filtrate from the old cultures reduces the number of sexual females. The losses by death are too few to account for the results obtained, and there is evidence to show that what deaths there are are not selective.

It is interesting to note the bearing of the above evidence on the question of starvation. It is not practicable to diminish the quantity of food placed in the dishes, without at the same time diminishing the quantity of other substances introduced. Several experiments were made to test the apparent effect of starvation. When the young were isolated, they were given only as much food as was judged necessary to support life and enable them to produce a moderate family. A control line, which was fed abundantly from the same cultures, was maintained in each case. One experiment, Table V, included 55 generations and covered a period of three months. In this time, the well-fed control varied so greatly in the proportion of sexual to parthenogenetic females produced, that it is important, not merely to note the totals, but to divide the experiment into periods, and compare the results in each.

TABLE V

Limiting Dates.	WELL-FED.			STARVED.		
	Sex. ♀	Parth. ♀	Per cent. Sex. ♀	Sex. ♀	Parth. ♀	Per cent. Sex. ♀
July 23–July 27	127	73	63.5	72	47	60.5
July 28–Aug. 25	50	754	0.6	125	265	32.0
Aug. 26–Sept. 5	129	153	45.7	55	80	40.7
Sept. 6–Sept. 20	35	203	14.7	34	100	25.3
Sept. 21–Oct. 12	187	261	41.7	93	157	35.2
Oct. 13–Oct. 25	25	208	10.7	87	161	35.0
Total	553	1,652	25.0	466	810	36.5

While the experiment as a whole shows a decidedly higher percentage of sexual forms in the starved families, there are parts of it that show a slightly lower proportion in the starved line. The variation in the percentage of sexual females from one period to the next in the starved line is of the same sign as in the corresponding periods of the well-fed line, but is smaller in every case. While the major fluctuations of the starved line occur simultaneously with those of the well-fed line, they are less in degree; the extremes of the starved series are always well within those of the well-fed. I can find only one factor which operated on both lines in the same way, but to less degree in one line than the other, namely, the food culture.

Of especial interest are the second and sixth periods Table V. In these, not only the *percentage,* but also the *absolute number*, of sexual females is higher among the starved individuals. This shows that the percentage is not raised by the mere elimination of some of the parthenogenetic females.

The experiment with starvation was repeated three times, each repetition including eight to sixteen generations. Each time there was a considerably higher proportion of sexual females in the starved families.

While it is conceivable that several factors may be at work producing these different proportions of sexual to parthenogenetic forms in the well-fed and starved families, the experiments with the filtrate from old food cultures show that the different quantity of dissolved substances incidentally given with the food is sufficient to explain the results. If this is the correct interpretation, the larger proportion of sexual forms in the starved families is not due to lack of food, but to the absence of chemicals which, in the well-fed families, prevent the appearance of the sexual forms.